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FOREWORD

In August 1985, the Fourth Biennial PARC Conference was held in Regina, Saskatchewan. At this time, discussion took place as to where the 1987 conference might be held. Winnipeg was one possible site, and it was decided that the Freshwater Institute in the newly structured Central and Arctic Region of the Department of Fisheries and Oceans would be an ideal location. Manitoba had not been chosen as a site since the first conference took place in Regina in 1979. It seemed appropriate for one of the group's founding members, Jan Barica, a research scientist, to support the Winnipeg location as he had worked there for many years.

The Plains fisheries resource has been a topic of concern for both federal and provincial bodies. Each of the speakers whose papers are published in this proceedings addressed major concerns to us all as aquatic researchers.

At all conferences, there are many people who work to guarantee the event's success, and my sincere thanks go to all of them. One of the original founders of the conference, Don Waite, made an outstanding contribution, as did Denis Windsor of Manitoba Hydro, and Bill Franzin, Department of Fisheries and Oceans, Winnipeg.

This symposium was jointly sponsored by the Department of Fisheries and Oceans, Manitoba Hydro, and the Canadian Plains Research Center. This last institution is publisher of these proceedings, and I would like to express my appreciation to Gillian Wadsworth Minifie, manager, CPRC Publications, who co-edited the papers and facilitated the publishing process, and Eilene Sabat, who produced the final draft of the papers which you now are reading.

Jim Gibson
Editor
Winnipeg, Manitoba

November 1988

ECOLOGY OF WALLEYES: IMPLICATIONS FOR COMMERCIAL AND SPORT FISHERIES ON THE CANADIAN PRAIRIES

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ABSTRACT

This paper describes the value of the present-day walleye fisheries, their current management practices, and the environmental requirements of walleye. Today's policies and biological needs are incompatible. The central Plains region of Canada contains the largest proportion of walleye habitat and produces the highest commercial yields. The value of the sport fisheries exceeds that of the commercial fisheries, although the former is not easy to quantify. Many commercial walleye fisheries in Canada are in decline due to changes in their habitat and excessive fishing. Perturbations to the environment cause changes in growth, survival, and recruitment, and thus alterations to the yield. Management can attempt to alter the physical habitat and control the fisheries. Successful stocking (a management tool) is difficult and can dilute the indigenous stock. This can be disadvantageous since the indigenous stock is probably better adapted to the given environment. The biologist is in the best position to make management policy, and biological considerations should be put before economic or social ones.

INTRODUCTION

Walleye, Stizostedion vitreum, have a wide distribution over North America, including the central Plains region. The Plains area contains 61% (24,974,000 ha) of available walleye habitat (Carlander et al. 1978). Over the years, commercial and sport fishermen have observed that many of the walleye populations have shown a steady decline in yield and they want to know the reasons for this. This paper describes the present-day walleye fisheries, outlines the environmental requirements of walleye, and makes some suggestions for their management. These suggestions are biased biologically, and they are deliberately provocative, with the aim of conserving present-day stocks of walleye for the future. Although this

paper applies to the walleye populations of the Canadian Plains region, it is probably also relevant to other walleye populations and to freshwater fishes in general.

Biological production of a population is the sum of growth of all members of that population, regardless of whether or not they survive to the end of the period being measured. It includes reproductive products which may be released during the time period. Yield is that part of production used by man. Since the late 1950s, yield of a fish population has been based mainly on the analytical model (Beverton and Holt 1957; Ricker 1958). This model was developed chiefly for single stock marine populations and was biological rather than economic. It takes into account the net effect of growth, reproduction, and mortality of individuals in the population. Today, with modern computers, the area under the curve created by the equation can be calculated easily. Any combination of realistic functions or actual values from field data can be included in the yield equation. Flexible fishery models result which simulate the effects of different managment policies. Estimating yields, whether they are maximum sustainable yields (MSY) or optimum yields (the latter can have different meanings to different people), is essential in the management of a fishery. However, yield is only one of the considerations of anglers who benefit also from the outdoor experience, environmental aesthetics, and the sporting challenge (Lackey 1978).

THE WALLEYE FISHERIES

The largest commercial catches of walleye are made in Canada but are sold predominantly in the central areas of the United States of America (USA). Most of the major walleye fisheries are located in the area which comes under the jurisdiction of the Freshwater Fish Marketing Corporation (FFMC). This area extends from northwestern Ontario to Alberta and north to the Northwest Territories. The FFMC, in the fiscal year 1985-86, exported 2,356 tonnes of walleye products and sold domestically only 463 tonnes (Canada Dep. Fish. Oceans 1987). In that year, walleye, with a market value of $20,063,000, represented 44 percent of the landed value of all freshwater fish caught commercially in the region. Fifty-one percent of those landed were from Lake Winnipeg (Table I). Quite a large proportion (42%) were caught in small lakes ('all others'). Many of these lakes have shown a steady decline in yields as is illustrated by Dauphin Lake, Manitoba (Figure 1).

Walleye are fished extensively throughout their range by anglers. It is almost impossible to put an overall value on these fisheries, but it is probably much higher than the value of the commercial fisheries. In the central region of Canada during 1982-83, the estimated direct expenditure on

Table 1: Landed weight (tonnes) and landed value (Can $1000s) for commercially caught walleye in the FFMC region during the year 1985-86. Also given are values for the major lakes. (Source: Canada Dep. Fish. Oceans 1987).

	Total	Lake Winnipeg	Lake Manitoba	Lake Winni-pegosis	Great Slave Lake	All Others
Landed weight (tonnes)	4,752	2,404	250	91	13	1,994
Landed value (Can. $1000s)	11,262	5,630	705	219	28	4,680

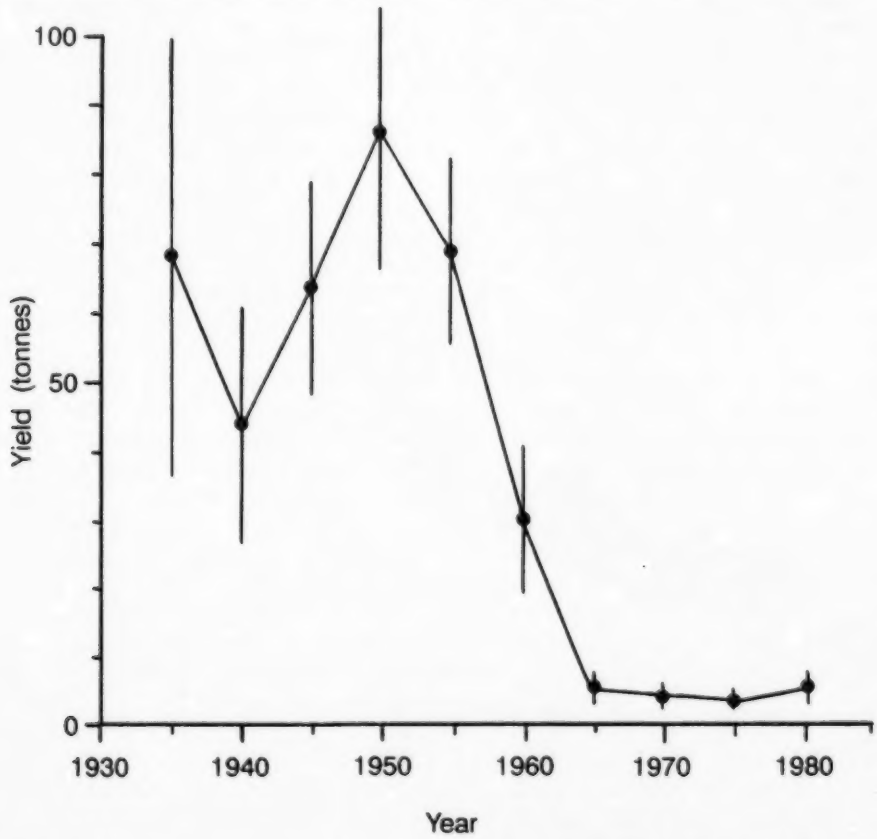

Figure 1. The commercial annual catch (tonnes) of walleye from Dauphin Lake 1935 to 1985. Values given are the mean and 95% CL for five year intervals.

all recreational fisheries was $680,271,000 compared to $57,490,000 for all freshwater fish landed by commercial fishermen (Craig 1987). The demand on lakes, rivers and reservoirs for angling is large, and in some cases may exceed supply.

The decline in walleye fisheries may be caused by detrimental changes to the walleye habitat and/or overfishing. For example, Regier and Hartman (1973) describe the changes that have taken place in the Lake Erie fish community due to environmental changes, and Colby et al. (1979) mention several walleye populations that have declined in numbers as a direct result of overfishing. Lysack (1986) states that the Lake Winnipeg walleye yields in the early 1970s increased rapidly after the fishery was closed during 1970-71.

FACTORS AFFECTING WALLEYE PRODUCTION

Growth

The growth of a walleye is influenced by two main environmental factors, temperature and competition, and by genetical considerations, although in the latter case the species appears to be very plastic. The relationship between these three factors and growth is complex, and it has not been elucidated as well for walleye as it has been for some salmonid species (Elliott 1975). At present, best estimates of potential growth can be simulated using bioenergetics models (Kitchell et al. 1977; Hurley 1986). Temperature effects are density independent and control the rate of metabolism. Optimum temperatures for physiological processes are 14-23°C for prolarvae, 21°C for postlarvae, 26°C for juveniles, and 23°C for adults (Hokanson 1977; Hokanson and Koenst 1986). Walleye grow more slowly the further north they live, a reflection of the reduction in mean annual temperature with latitude (Colby and Nepszy 1981). Heated effluents and water level control may have a significant effect on walleye growth as they affect water temperature. Competition for food, both intra- and interspecific, is density dependent and affects growth at all stages of life history except the egg stage (Colby et al. 1979). Culling of walleye stocks often results in increased growth of the remaining individuals. This has recently been illustrated in the South Basin of Lake Winnipeg (Lysack 1986). The influence of other predators, such as northern pike (Esox lucius), which are commonly found in the same habitat as the walleye and which feed on the same prey, needs further investigation and quantification. The study of walleye populations should always be approached from a community standpoint; in other words, how the walleye relates to other organisms in the system. The quality of food may also be important, with a diet of fish producing better growth rates than that of invertebrates (Forney 1966).

Walleye exhibit dimorphic growth (Figure 2) and the faster-growing females may become vulnerable to fishing gears before the males. This may have a significant effect on spawning escapement.

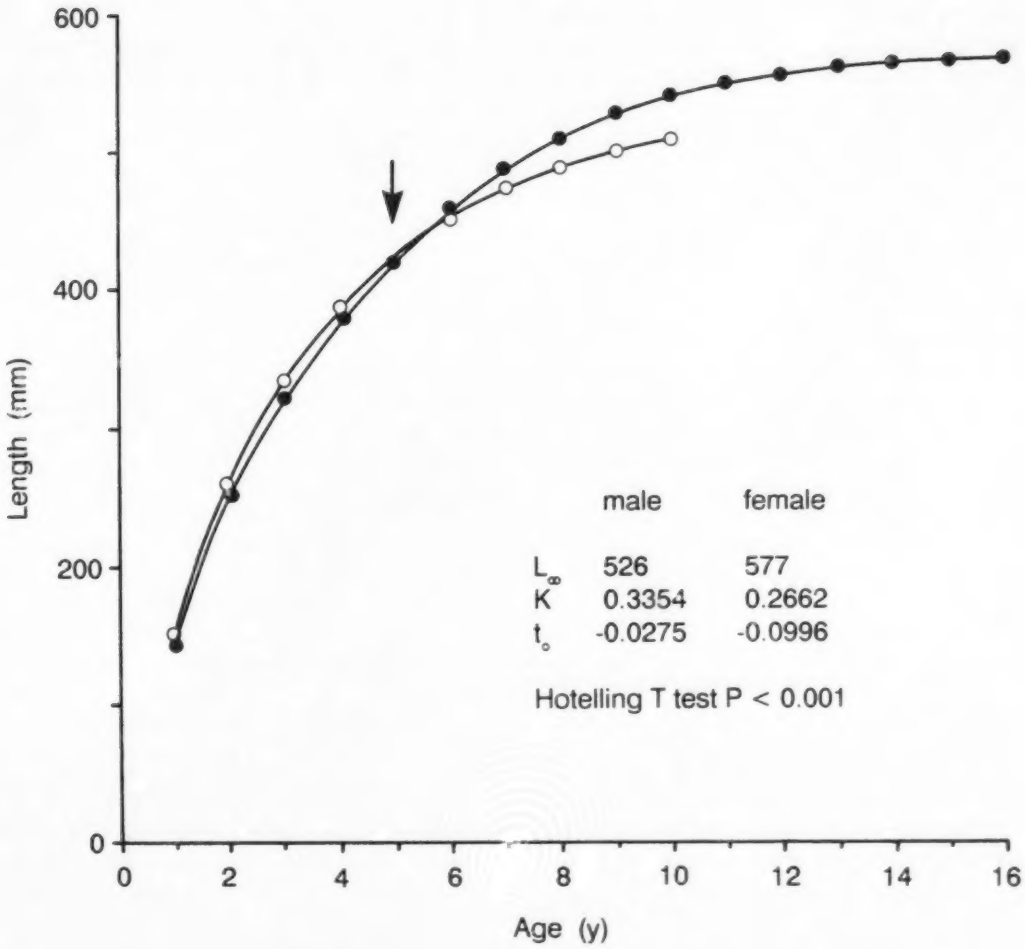

Figure 2. Von Bertalanffy growth curves for male (O) and female (●) walleye from Dauphin Lake, Manitoba. Statistics for fitting the curve are given. The arrow indicates first age of maturity for female walleye.

Natural mortality

Natural mortality of walleye varies with age and is strongly influenced by external factors. The mortality rate is highest in the first year of life and then declines to an almost steady rate throughout life, increasing again only as the fish reach old age (Colby et al. 1979). Walleye mortality in the early stages may be density dependent; faster-growing individuals survive better than their slower-growing peers. The mortality rate later in life is probably not density dependent. Mortality in the early stages will be discussed more fully under recruitment. Natural mortality can vary considerably between populations and between and within year classes. At the optimum temperature for growth, the growth rate is at a maximum. Fast growth leads to early maturation. Speeding up of physiological processes in fish may induce the early release of immune responses and result in early senescence and death (Craig 1985). Walleye living in cold northern latitudes live longer than fish in warmer southern areas (longevity varies between about 3 and 19 years). Female walleye in the southern USA mature at 2 years as compared to 10 years in the Northwest Territories.

Recruitment

Recruitment of walleye to a fishery is dependent on survival and thus is an extension of the foregoing discussion. The processes involved are summarized in Figure 3 (see Colby et al. 1979; Craig 1987). The variability of survival from year to year (year class strengths) is a familiar feature of percid populations. When the fluctuations become extensive, it is often a sign that the population has been severely perturbed and is in an unstable state (Nepszy 1977). All the factors shown in Figure 3 can alter the year class strength (YCS) although some have more influence than others. For instance, Shuter and Koonce (1977) found that they could predict YCS for western Lake Erie walleye from the adult stock size and the rate of water temperature increase during the spring. Lysack (1986) produced predictive models for estimating YCS from female spawning mass, flow rates of afferent rivers and vernal warming rates in Lake Winnipeg. The influence of climatic conditions is further emphasized by lakes in the same area often showing the same fluctuations in YCS (Colby et al. 1979).

Stocking lakes with walleye is an established practice. In bodies of water which have sustaining populations the stocking is rarely successful (Laarman 1978). If conditions are favourable, the indigenous stock will produce an adequate year class. If natural conditions are not good for the early stages, the timing of the stocking is vital so that the introduced walleye miss the unfavourable period and enter the water at an optimum time. In this way, the introduced fish

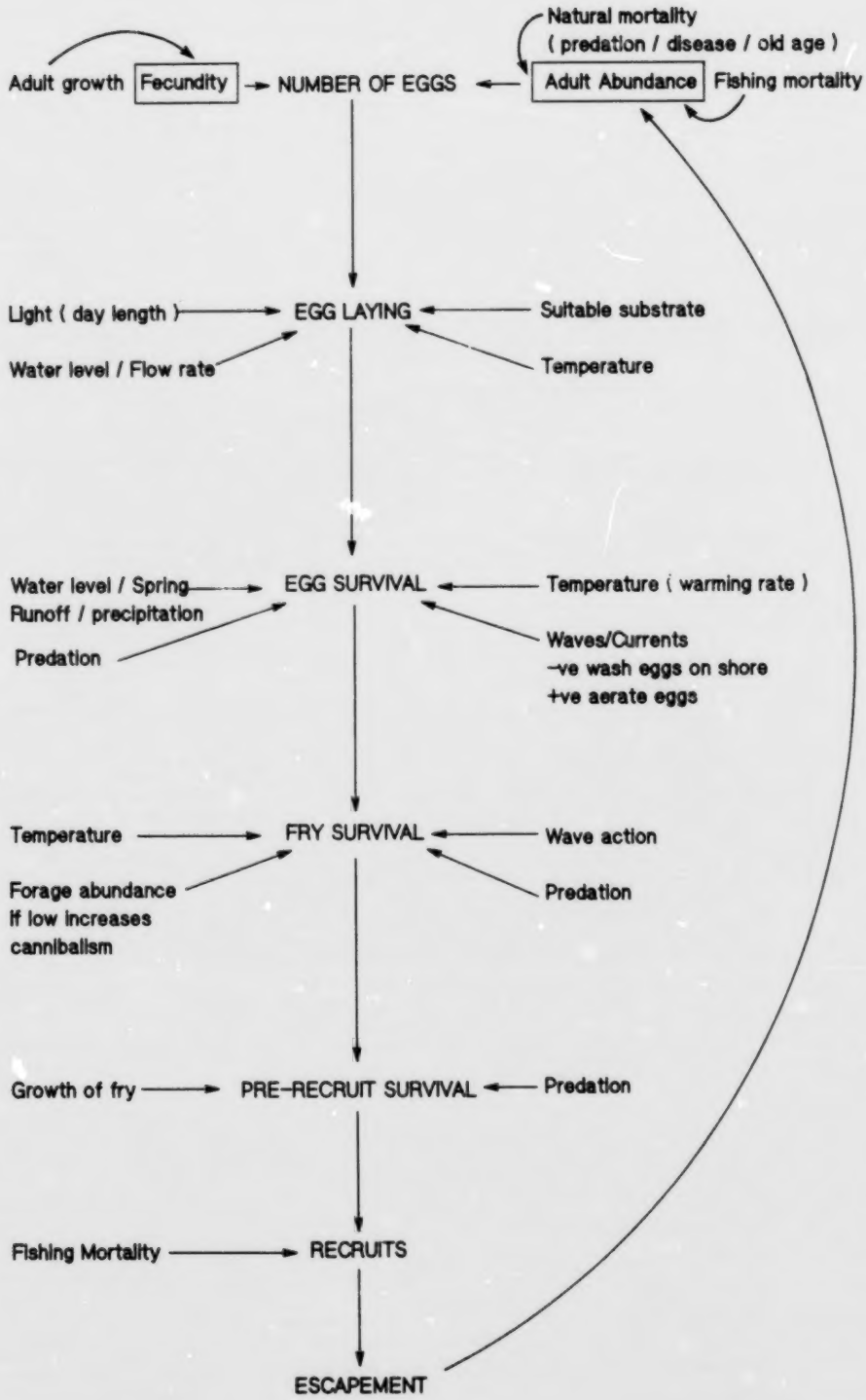

Figure 3. A summary of the factors affecting the recruitment of walleye.

may succeed while the indigenous stock fails. The theory behind this is illustrated in Figure 4.

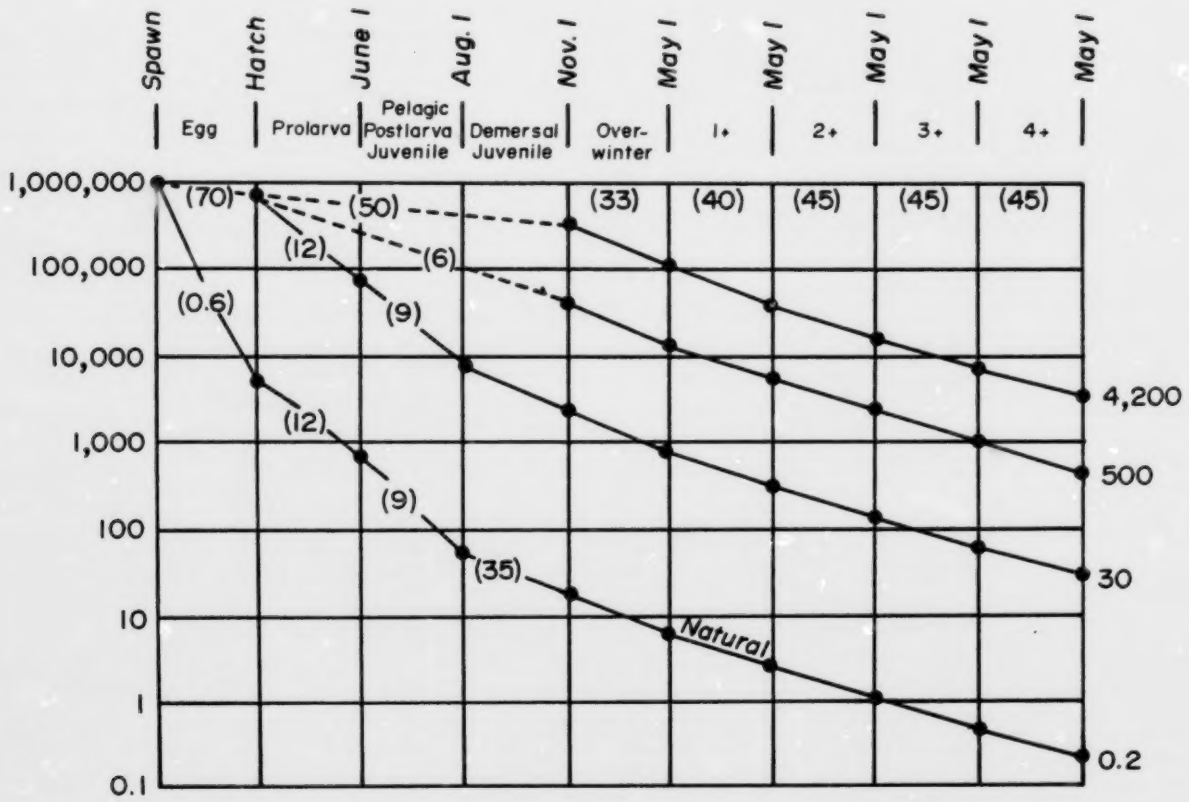

Figure 4. A diagram to illustrate the effects of varying survival on a starting population of one million eggs. If natural conditions are poor the population undergoes low survival in early life, the bottom line. The three upper lines represent populations which have been raised to various stages. If environmental conditions are good, the natural population could follow one of the upper lines. All populations are subjected to fishing pressure after the juvenile phase. Figures in brackets are survival rates (%), others are actual numbers remaining from one million fertilized eggs. (Craig 1987 after Mathias in prep.).

MANAGEMENT: PRESENT ATTITUDES - FUTURE PROSPECTS

Management of walleye stocks can be considered from two aspects, control of the environment and control of the rate of fishing mortality (or escapement). There are a number of difficulties in controlling the environment. Not least are the multiple uses to which inland waters are put. However, there is no doubt that improvement can be made to recruitment by controlling, at critical times in the life cycle, such factors as spawning substrate, flow rates, water levels, and power plant and pollutant discharges. Managers may also consider the control of predators and competitors.

Usually, fish stocks have been managed with the aim of producing a maximum yield but without reducing the populations below their ability to maintain the yield. This is the familiar maximum sustainable yield concept. Attempts have been made to control the rates of commercial exploitation by various means such as gear control, season control, limited entry, and non-transferable and transferable quotas. Closed seasons, bag limits, and minimum and maximum sizes have been used to control angling pressure. However, competition for the limited resource among fishermen, be they sport or commercial, often leads to overall catches which cannot be sustained. The situation is probably not helped by governments which subsidize fisheries, or local politicians who may bend towards their constituents against the advice of professionals. Management of walleye fisheries needs a scientific basis. This may lead to telling the customer what he should have, rather than supplying him with what he wants. There is no doubt that walleye fisheries need to be exploited below the maximum sustainable yield. But what is the optimum yield? Is it decided by the biologist, or the economist, or the politician, or the sociologist? Healey (1984) has described a method of multiattribute analysis in the determination of optimum yield. A wide range of biological, economic, and social factors are used in the determination. But, even with an analytical model of this kind, the values given to each factor are subjective. In this regard, I believe in conserving the present stocks and I follow the views of Larkin (1977) that the biological risks should be measured and from these the rates of harvesting should be determined. The number of fishermen and their fishing power is then set. The remaining fishermen can be employed somewhere else. Thus, the fish should be considered first, the economics second, and the social problems a distinct third. It is possible that if overfishing and man-induced changes to the habitat continue, in the near future the walleye fished in lakes and rivers will be those that have been stocked there from a hatchery. A problem with this stocking is the replacement of indigenous stocks with walleye less adapted to their new environment. This may be overcome by using mobile hatcheries or fixed hatcheries located beside the water body

to stock local walleye larvae.

CONCLUSIONS

Walleye stocks have taken thousands of years to adapt to their particular habitat. Increased fishing pressure and other perturbations to their environment have put the populations at serious risk. Biologists are still not fully equipped to make sound quantitative predictions on the response of walleye populations to changes in the environment, natural or man induced, although a number of models show promise. However, the biologists are best informed to give advice on the management of these stocks. They are the professionals in this area and their work is valueless if it goes unheeded by politicians and economists.

ACKNOWLEDGEMENTS

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INTERBASIN TRANSFER OF FISHES IN THE PRAIRIE REGION AND ITS IMPACT ON FISHERIES

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ABSTRACT

Interbasin transfer of biota has long been a concern in fisheries management. The Garrison Diversion Unit (GDU) is a potential source for interbasin biota transfer from the Missouri River drainage to the Hudson Bay drainage. Species of concern that could traverse basin boundaries include rainbow smelt (Osmerus mordax), gizzard shad (Dorosoma cepedianum), numerous species of salmonid viruses, and one coelenterate parasite. The concern of any such introductions is that they may adversely affect existing fisheries.

The literature suggests that simplistic systems, such as those found in the prairies region, are conducive to the establishment of introduced populations. Those species of fish that are able to enter systems and maintain a population are "generalists" and can quickly assume dominance.

There are documented accounts of intentional introductions of non-native and exotic fish species in the prairie region. Some of these have been beneficial while others have been shown to be detrimental to indigenous fish populations. Impacts, whether positive or negative, are largely a function of local attitude. Careful planning and analysis of short-term and long-term effects must be considered when there is a potential for an introduction.

The subject of interbasin transfer of biota, particularly fish, has gained a great deal of notice in the upper Plains region in the past 20 years. Much negative notice and comment has focussed on the Garrison Diversion, a large water development project that plans for the diversion of water from Lake Sakakawea on the Missouri River to the eastern part of North Dakota for irrigation, municipal, rural and indus-

trial water uses. Some of the water is scheduled to be transported across the continental divide into the Hudson Bay drainage via open waterways. As a result of this water diversion there is the possibility of interbasin biota transfer and the potential for impacts resulting from biota transfer. Although this paper deals solely with the transfer of fish species and the reasons, methods and establishment of such introductions, it is appropriate to mention the potential for other transferals as a result of the Garrison Diversion. Among the parasites are Polypodium hydriformes, a coelenterate parasite on the eggs of paddlefish, and there are also numerous salmonid viruses.

There are several methods by which biota transfer can occur and these fall into three categories: (1) intentional, including state, federal or provincial stocking programs; (2) unintentional, the most common form being bait bucket transfer, although sometimes this may be intentional as well as illegal; (3) the unintentional intentional - that is when a water project is built, or a lake is stocked, with the knowledge that a non-native or exotic species has ample opportunity to be introduced and established but it appears it probably will not move into the new aquatic system. Methods of transfer can be categorized in many ways, but the final question is: "What are the impacts of the introduction of this species on the fish community of the system?"

This paper has referred to non-native and exotic species of fish. The American Fisheries Society (AFS) Exotic Fish Section has adopted the following terminology: introduced fish are those which have been moved from one place to another by man; exotic fish have been introduced from a foreign country; and non-native transplant fish are organisms that have moved outside their native range, but within a country where they occur naturally (Kohler 1986; Shafland and Lewis 1984). There are arguments as to the accuracy of these definitions, but these terms will be used in their referenced context in this paper.

In North Dakota, non-native and exotic fishes have been transplanted into state fisheries waters since fisheries management was officially implemented in the mid-1900s. Transplants have included the now famous rainbow smelt (Osmerus mordax), coho salmon (Oncorhynchus kisutch, chinook salmon (Oncorhynchus tsawytscha), rainbow trout (Salmo gairdneri), brown trout (Salmo trutta), lake trout (Salvelinus namaycush) and others that are too numerous to mention (Table 1). Mysis relicta was introduced into Lake Sakakawea in 1974 and 1979. Luckily it did not establish itself as a viable population; there are accounts of this species annihilating zooplankton in an aquatic system. The primary purpose for such transplants is to provide new species for angling or to supplement a forage base, largely

Table 1: Non-Native Organisms Introduced by Man Into North Dakota Waters

Species	Year of initial introduction
Rainbow Smelt (Osmerus mordax)	1971
Chinook Salmon (Oncorhynchus tsawytscha)	1976
Coho Salmon (Oncorhynchus kisutch)	1969
Rainbow Trout (Salmo gairdneri)	1955
Brown Trout (Salmo trutta)	1964
Lake Trout (Salvelinus namaycush)	1973
Lake Whitefish (Coregonus clupeaformis)	1974
Sacramento Perch (Archoplites interruptus)	1963
Grass Carp (Ctenopharyngodon idella)	1972
Common Carp (Cyprinus carpio)	?
Striped Bass (Morone saxatilis)	1977
Cutthroat Trout (Salmo clarki)	1979
White Bass (Morone chrysops)	1971
Brook Trout (Salvelinus fontinalis)	1971
Muskellunge (Esox masquinongy)	1958
Oppossum Shrimp (Mysis relicta)	1974, 1979
Largemouth Bass (Micropterus salmoides)	late 1800s
Smallmouth Bass (Micropterus dolomieui)	late 1800s

to create a better and more diverse recreational fishery for the public. The fishery management objective in North Dakota is to maximize and sustain a multi-use recreational fishery, thus providing the most diverse and best possible opportunity for anglers. Transplants and exotics, such as those mentioned, can be important tools in fisheries management if stocking is conducted on a sound ecological basis (Courtenay and Taylor 1986).

There are several reasons for introductions of fish species into an aquatic system as cited by Welcomme (1986). The first is to improve recreational fishing. Although the walleye is native to the upper Great Plains area, walleye and northern pike are consistently stocked from one drainage to another. A specific gene pool may be diluted by doing this, but if there is an adverse reaction, it is not known at this time. Second, the productivity of water bodies may be improved by converting unexploited trophic resources into fish yield. Essentially, this fills a vacant niche. A niche has been defined in many different ways, but Odum (1971) has the simplest and most encompassing definition. He simply states that a niche is "the physical space occupied by an organism and its functional role in the community." This definition contains an infinite number of biological and physical parameters, but it is applicable in describing differences or

similarities between two or more species. These first two reasons for introductions provide the primary purpose for transplants or exotic introductions into North Dakota. The first involves the salmonids already mentioned, and the second revolves around the rainbow smelt, which was introduced into Lake Sakakawea in the early 1970s to supplement a declining forage base. The salmon were also used to fill the "vacant niche" of the deeper waters. Welcomme (1986) cites as the third reason for introductions the control of undesirable aquatic organisms. As is seen in Table 1, which lists introductions into North Dakota waters, grass carp were introduced in 1972 into Spiritwood Lake for experimental control of submergent aquatic vegetation. They did control aquatic vegetation to some extent but in the process likely destroyed some escape habitat used by indigenous fishes. Even though it was experimental, and in a closed basin, this was a remedy rather than a cure. The excessive vegetation was a result of large amounts of agricultural runoff entering the lake which exacerbated an already serious problem. Other reasons for introductions are: fourth, aquaculture; fifth, ornament; and sixth, nonpurposeful introductions.

Welcomme (1986) cites five potential problems with transfers. These are: (1) introduction of diseases; (2) disruption of the fish community in which the introduction has occurred through competition or predation; (3) genetic degradation of host stock (hybridization, thus diluting the adaptive suitability of the indigenous population (Crossman 1984)); (4) degradation of the environment by the introduced species, leading to indirect disruption of the aquatic community; (5) disruption of human life styles, customs, or economic systems associated with use of the natural resource.

When an exotic or non-native fish species is introduced into an aquatic system, a perturbation occurs and a readjustment must be made by the ecosystem to bring itself back into balance. This adjustment may be minor - reduced growth rates of competitor species, for example - or it may be on a very large scale - eradication of competitor species (Courtenay and Taylor 1986). The smaller the lake, the fewer ecological niches there are available; therefore, there is a less diverse species assemblage. Evolution has provided for full and efficient utilization of the existing niches by creating an equilibrium between rates of immigration (or introductions) of new species and the extinction (or negative impacts) of existing species (Magnuson 1976). Therefore, the smaller and more established lakes with a viable fish community have a great potential to be severely impacted by introductions. Smaller waters are not the only ones to be severely impacted by such introductions, however. Temperate waters are generally simpler, having less species diversity than those waters in tropical or subtropical areas. Therefore, impacts are generally realized more quickly and can be

of a greater magnitude (Welcomme 1984). Waters in the upper Great Plains region are temperate. Of course, an indiscriminate introduction of any species will not automatically cause an impact. The life history of the species needs to be taken into account. For example, a cichlid introduction, which would probably survive and be successful in the subtropical waters of Florida, would probably not survive the harsh winters experienced in the upper Great Plains. Conversely, most salmonid introductions into a warm water, tropical system would probably not be successful. However, it is known that if life history requirements are met for an introduced species, the potential for a negative impact is greatly enhanced. This is particularly true if there is any niche overlap and the introduced species is adaptable to a wide range of physical, chemical and biological conditions. Some attempts have been made to replace evolution by introducing new species, building dams, and causing other deleterious effects to aquatic systems.

The primary question most often asked when any new species is introduced into a system, whether an exotic or a transplant, is "Will it cause an impact?" There are two kinds of impacts, positive and negative. When the word "impact" is used, most people immediately assume that the term is negative and, for the most part, it is. However, the question that should be asked is "Will the introduced species survive and serve the purpose it was placed there for, and will it cause a significant negative impact?" To answer this question, the constraints and advantages that an introduced species faces relative to the establishment of a self-sustaining population must be weighed. The structure of a community receiving an introduction is important in determining whether the introduced species becomes established. The introduced species is often removed from one environment that limits its abundance to another in which it may flourish uncontested (Taylor <u>et al</u>. 1984). Biologists should know the answer to this question before an introduction occurs, whether the introduction is intentional or unintentional. When a non-native organism enters an aquatic system, there is always a risk because understanding about individual dynamic ecological systems is limited. The risk is not with the species being introduced into a system. Rather, the risk lies in not knowing <u>exactly</u> how the organism will react in the new environment (Courtenay and Taylor 1986). The successful introduction must be able to acclimate to a wide range of environmental conditions. The success of any introduction may lie in the ability to maximize r and k strategies concurrently. According to Stauffer (1984), r strategists are more commonly successful in temperate areas, while k strategists are more successful in tropical and subtropical areas. So, when it is determined whether or not an introduced species can survive and establish a self-sustaining population, that answers the first part of the question.

What about the impact? Judgement on the success, failure, or impact of introductions can only be made in a wide temporal, ecological, and socio-economic context (Welcomme 1986), and is essentially a matter of local attitudes (Welcomme et al. 1983). For example, the introduction of rainbow smelt into Lake Sakakawea was considered to have saved the walleye/ northern pike fishery and, in later years, allowed establishment of the chinook salmon fishery. The rainbow smelt were, in fact, instrumental in increasing condition factors of walleye, as is evidenced by Table 2. Rainbow smelt were introduced into Lake Sakakawea in 1971 and reached a viable population in the mid-1970s. It can be seen how condition factors, therefore fecundity, increased. Nevertheless, the walleye population has declined, but not as a result of the presence of smelt. Rather, it is considered a function of spring water levels, and weather conditions that are not conducive to successful natural reproduction. Chinook salmon, another introduction, heavily utilize smelt throughout most of their short life span (Aadlund 1987). The introduction of smelt into Lake Sakakawea appears to be successful, although the long term impacts have not been realized. In North Dakota, numerous measures have been introduced in an effort to repair what man has broken. Natural aquatic ecosystems have been disrupted by dam construction, pollution, water development projects, and agricultural runoff. Approximately 65% of North Dakota's waters managed as recreational fisheries are manmade. The remaining 35% are natural waters that are marginal in maintaining a viable sport fishery. Destruction of old niches suitable for indigenous populations in manmade waters, and the lack of individuals to sustain populations in natural waters, force us to resort to introductions. Sometimes these introductions are native species, and sometimes they are not. It has been stated that introductions should not be used as a substitute for other managerial strategies (Courtenay 1979), as was the case for grass carp in North Dakota. Other strategies, such as lake aeration, habitat manipulation, and hypolimnetic drawdown, have been implemented with some success. However, many fisheries management strategies are underfunded in North Dakota, a primarily agricultural state where agriculture receives the greatest proportion of governmental financial support. Recreation is the second most important facet of the economy in the state, recently surpassing minerals and mining; while fisheries play a large role in recreation, lack of funding results in an inability to provide recreation in a short term effort. This in no way indicates that new species would not be introduced into North Dakota fisheries waters, but our managerial alternatives are greatly reduced. It must be remembered that the objective is to provide the best fishing possible for the angling public. In spite of the fact that the majority of introductions have been successful, introductions will not work everywhere. The rainbow smelt is a perfect example. It has served its purpose perfectly in Lake Sakakawea but, at

Table 2: Average Annual Growth Increments for Walleye Collected from Lake Sakakawea

Author	Year	I	II	III	IV	V	VI	VII	VIII	IX	X
Wahtola et al. (1972)	1968	149	94	75	68	70	65	23	57	95	40
Wahtola et al. (1972)	1969	147	93	74	70	56	57	57	18	22	
Cassity (1979)	1978	144	98	84	81	59	46	73	65	43	
Hiltner (1983)	1982	192	79	77	64	56	46	42	38	23	25

Condition Factors (K(TL)) of Walleye Collected from Lake Sakakawea

Author	Year	K(TL)
Wahtola et al. (1972)	1968	0.88
Wahtola et al. (1972)	1969	0.89
Cassity (1979)	1978	0.85
Power (1987)	1978	0.87
Power (1987)	1980	1.01
Hiltner (1983)	1982	1.04
Power (1987)	1984	1.09
Power (1987)	1986	1.11

the time of its introduction the system had been drastically changed from a fast-moving river system to one of deep, cold water habitat with the characteristics of a slow-moving river. This provided smelt as well as salmon habitat. It was essentially an unused part of the system, an available niche. The impacts from rainbow smelt in North Dakota were for the most part positive. The state does not have a large

commercial fishery for game fish such as walleye, lake whitefish, or lake herring. Lake Winnipeg, however, has an indigenous fish community that has essentially stabilized itself during its period of evolution and, as stated before, any perturbation can cause a large negative impact. The risk of any unintentional introduction into Lake Winnipeg may far outweigh the benefit. For example, the impact could result in a reduction of the commercial catch of lake herring and negative impacts to the economy. The driving force for all impacts is economics. Fishery biologists are not concerned with economics from an ecological perspective but as fishery managers, they must be concerned.

Even under the Garrison Diversion Reformulation Act of 1986 there is potential for the interbasin transfer of rainbow smelt. The potential lies in the unintentional and unintentional/intentional categories mentioned earlier. The movement of two drainage systems closer together will always enhance the possibility of bait bucket transfer. It has often been stated that smelt move down a system quickly. This was the case in the Missouri River when they moved down as far as Nebraska within a few years after they were established. There is no evidence that they have established themselves in Lake Audubon yet, neither have they been found past the headworks of the McClusky Canal. Monitoring smelt movement and abundance within the canal continues. Gizzard shad, once a species of concern, have become a minor issue. Although shad were found for the first time in the lower James River of North Dakota in 1986, the Reformulation Act cut off all avenues of introduction, other than bait bucket transfer, into the Hudson Bay drainage. The possibility of bait bucket transfer is still present, but it is greatly reduced.

To prevent impacts, or at least lessen their severity, the public and fisheries biologists must be educated to consider the consequences of such occurrences, and to weigh the benefits against the risks. Neighbouring states, provinces, or governments that have the potential to be impacted should share information on interbasin transfers. This is not always done, and there have been unfortunate consequences. Li and Moyle (1981) have developed a system of loop analysis that may provide a better insight into what impacts might accrue as the result of an introduction. My own method of determining what an impact will be is simple: the system's food web is depicted and the introduced species placed into the picture. With the appropriate life history information, changes that may theoretically occur, <u>if the organism reacts as expected</u>, can be predicted no matter what method is used to determine impact. The point is to make the public and the responsible entities aware of the potential impacts.

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FISHERIES ENHANCEMENT INITIATIVES IN THE PRAIRIE REGION

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ABSTRACT

Fishery enhancement activities include the restoration, rehabilitation and enhancement of fish habitat, as well as measures to increase fish populations using techniques of aquaculture and fish stocking. These programs are increasing in the prairie provinces in response to a narrowing gap between the harvestable supply of fish and the demands of sport, commercial and domestic fishermen. The type of fishery enhancement program offered differs among the prairie provinces, reflecting local geography, the distribution of fish species, and the relative strength of sport and commercial fishing interest. The costs of fish habitat rehabilitation are high, and offer some perspective to the value of protecting fish habitat during land development.

INTRODUCTION

Fisheries enhancement generally refers to an improvement in fisheries quality. The size of a fish stock might be increased by stocking fingerlings into a lake. The carrying capacity of a stream may be raised by creating riffles and pools where none existed. Habitat suitable for trout may be created close to a major city by damming a stream or excavating a new pond. A lake which undergoes winterkill may be aerated with an air compressor to rehabilitate otherwise unuseable habitat. The concept of fisheries enhancement includes both the addition of new resources and the restoration of resources which have been degraded by other land use practices.

The first step in protecting the quality of a fishery is regulation of harvest by fishery management. Fishery enhancement measures are often a secondary response to declining fishing quality, because they are more costly to implement. Enhancement programs, therefore, are usually a clear

signal that the fisheries harvest potential is declining below the harvest demand. This point has been reached by some of the important sport and commercial species on the Canadian prairies during the past 15 years, and most fisheries will have reached a demand/supply imbalance by the year 2000. (Saskatchewan Dep. Tour. Renew. Resour. 1982, Alberta Dep. Energy Nat. Resour. 1984; Green and Derksen 1984)

THE RESOURCE BASE

Saskatchewan contains 94,000 bodies of water covering 6.7 million hectares. These waters range from the large, deep, unproductive Lake Athabasca (7,900 km^2) in the north, to small shallow productive lakes in the south such as Buffalo Pound lake (area 26 km^2, and depth 5.6 m). Of these, 50,000 are estimated to contain fish (Saskatchewan Dep. Tour. Renew. Resour. 1982). Many bodies of water which do not ordinarily contain fish provide important fish habitat for migration, spawning, and nursery areas during the spring.

Manitoba contains 55,330 lakes. If the three largest lakes, Winnipegosis, Winnipeg and Manitoba, are excluded, the smaller lakes comprise 7.8 million hectares. Of these, only 8% lie in the southernmost quarter of the province where the main population density lives. (Green and Derksen 1984). Inclusion of the three large lakes brings the total lake area to 11.2 million hectares.

In Alberta, 45,000 km of stream habitat have been identified as habitat for trout and mountain whitefish. The province also contains some 1,100 lakes, comprising 3 million hectares, which are habitat for trout and other species of fish (Alberta Dep. Energy Natur. Resour. 1983).

There are several broad trends in fisheries development across the prairie region which have their origins in geography. A common characteristic of the three prairie provinces is that all contain a southern geological region containing true "prairie" lakes, as well as a northern ecological region of lakes on the Canadian shield. The larger of the "shield" lakes contain lake trout, more northern lakes contain arctic grayling, and many streams are habitat for arctic char; all these waters support popular sport fisheries. Whitefish are the most important commercial species in the north. The more productive and warmer "prairie" lakes are habitat for walleye, northern pike, yellow perch and whitefish. It is the southern lakes and streams which are targeted most often for enhancement. They are closer to the urban centres and sustain higher fishing pressure than the northern lakes, and their location in prairie farmland leads more frequently to degredation by surrounding land use practices.

Several sociological and economic factors are also broadly similar across the Canadian Plains region, and these present common problems for the management of fisheries. Population growth is low, but positive, and growth in the tourist sector is encouraged in all prairie provinces. This puts continuous, increasing pressure on the sport fishery, and licence sales are doubling every 15 to 26 years, depending on the province (Table 1). In Saskatchewan, 75% of the total number of lakes will be accessible to anglers by 1990 (Saskatchewan Dep. Tour. Renew. Resour. 1982). In Manitoba, the demand for northern pike and walleye was about 71% of supply in 1980, and it is estimated that the demand will equal the supply by 1990-92 (Green and Derksen 1984) In Alberta, the demand for trout had reached 90% of supply by 1980 (Alberta Dep. Energy Natur. Resour. 1983). It can be seen that, in general, the demand for sport fishing is increasing rapidly and will equal or exceed the rate of supply within the present century.

Table 1. Rate of increase in sport fishing demand in the Canadian Prairies.

	Alberta (1975-1980)	Saskatchewan (1950-1980)	Manitoba (1950-1983)
Annual % rate of increase in sport fish licence sales	2.6	4.5	4.1
Number of years for licence sales to double	26	15	17
Demand will equal supply in:	-	-	1990-1992
Percent change in number of sport fish licences (1980-1985)	+11.3	+8.90	-4.4

Sources: Saskatchewan Dep. Tour. Renew. Resour. 1982; Alberta Dep. Energy Natur. Resour. 1983; Manitoba Dep. Natur. Resour. 1985; Canada Dep. Fish Oceans 1988a, 1988b, 1988c; Green and Derksen 1984.

In all areas of the prairies, adverse land use practices, such as pollution, road building, siltation, mining, logging, industrial activities, and drainage have led to the deterioration of fish habitat and have been responsible for the loss of fisheries directly and indirectly. Agriculture

has undoubtedly had the greatest adverse affect upon fisheries because of the pervasive environmental changes it brings about. Section roads and field drainages modify fish habitat physically, while pesticides, fertilizers, and siltation modify it chemically over vast areas of the cultivated prairies.

As fishery resources become scarcer, questions of allocation become more serious. Increasing competition exists between commercial and sport fishermen, and between Native fishermen and the other two groups. All three prairie provinces recognize certain rights of Native people to catch fish for domestic use in designated areas; the provincial governments are also committed to the support of commercial fisheries. These conflicts impinge upon fishery enhancement programs, because recreational use groups, which support enhancement through licence fees, demand that the money be spent on sport fishing, while commercial and domestic fishermen also want fishery enhancement to benefit their needs.

Geographical differences underly dissimilarities among provincial fisheries. The presence of three extremely large prairie lakes in Manitoba permits a large commercial fishery, whereas in Alberta, the foothills of the Rocky Mountains are rich in stream habitat, and the emphasis there turns more to a recreational trout fishery. This trend can be seen in the harvest and value of commercial fisheries in the three provinces (Table 2). In 1980, the commercial harvest was 15,500 tonnes in Manitoba, about 5,000 tonnes in Saskatchewan, and only 2,000 tonnes in Alberta. The respective values of these harvests were $13 million, $4.9 million, and $1.5 million.

Table 2. Profile of the commercial fishery in the prairie provinces of Canada.

	Alberta (1980)	Saskatchewan (1980)	Manitoba (1982-83)
Number of fishermen	2,300	1,372	2,459
Total Harvest (Tonnes)	1,943	4,900	15,500
Value ($)	1,500,000	N/A	13,000,000

Sources: Saskatchewan Dep. Tour. Renew. Resour. 1982; Alberta Dep. Energy Natur. Resour. 1983; Manitoba Dep. Natur. Resour. 1985; Green and Derksen 1984.

In contrast, sport fishing plays a stronger role in Alberta than in Saskatchewan or Manitoba (Table 3). The harvest of sport fish in 1985 was twice as high in Alberta as in the other two provinces, reflecting in part a larger population of active anglers, but also a greater fishing effort in terms of the number of fishing days per angler. In consequence, the annual investment in sport fishing in Alberta was about $155 million in 1980 (Table 4), compared to about $70-80 million in each of the other two prairie provinces. These investments contrast with annual investment expenditures for commercial fisheries of $1.5 million in Alberta, $4.7 million in Saskatchewan, and $35 million in Manitoba. Clearly, sport fishing in the Canadian prairies has a far greater economic impact than commercial fishing. It is also interesting to note the extraordinary growth in expenditures for sport fishing which took place in the prairie provinces between 1980 and 1985. Alberta and Manitoba recorded a 90% increase in expenditures, while growth in Saskatchewan was 110%. These changes indicate the rapidly increasing importance of sport fishing across the prairies.

Table 3: Profile of the sport fishery in the prairie provinces of Canada.

	Alberta (1985)	Saskatchewan (1985)	Manitoba (1985)
Number of angler-days	5,372,200	1,946,043	2,684,000
Fish harvest (No.)	11,214,400	4,767,959	4,295,201
Fish harvest (Kg)	6,996,000	4,227,006	4,399,381
Number of Licenced anglers from:			
In-province	331,152	159,593	146,863
Canadian (other)	6,277	24,046	7,730
Foreign	5,881	18,738	32,579
Total licenced anglers	343,310	202,377	187,172
Total active anglers (including children)	430,753	248,899[a]	240,198[a]

[a] includes adults over 65 years who do not have to purchase a licence.

Sources: Canada Dep. Fish. Oceans 1988a, 1988b, 1988c

Table 4: Economic profile of the annual value of fisheries in the prairie provinces of Canada.

	Alberta (1980)	Alberta (1985)	Saskatchewan (1980)	Saskatchewan (1985)	Manitoba (1980)	Manitoba (1985)
Sport Fishery	(millions of dollars)					
Capital expenditures	92.0	162.2	28.0	80.7	48.2	85.4
Operating expenditures	62.6	132.5	41.9	70.7	35.9	73.9
Persons employed[a]	1,050	N/A	732	N/A	856	N/A
Commercial Fishery	(millions of dollars)					
Capital investment	1.5*	N/A	2.5	N/A	35.0[b]*	N/A
Operating investment		N/A	2.2	N/A		N/A
Persons employed[c]	2,300	N/A	1,114	N/A	4,420	N/A
Domestic Fishery	(thousands of dollars)					
Capital investment	N/A	N/A	19.6	N/A	N/A	N/A
Operating investment	N/A	N/A	27.0	N/A	N/A	N/A

* For Alberta and Manitoba, capital and operating investment are combined
[a] includes outfitters only
[b] includes fishermen, processing and marketing (Anon 1985b)
[c] includes licenced fishermen only

Sources: Saskatchewan Dep. Tour. Renew. Resour. 1982; Alberta Dep. Energy & Natur. Resour. 1984; Manitoba Dep. Natur. Resour. 1985; Canada Dep. Fish. Oceans. 1988a, 1988b, 1988c; Green and Derksen 1984.

In addition to the sport and commercial fisheries of the prairie region, there are three other fishery activities:

the Native domestic fishery, the bait fishery, and aquaculture. Of these, only the domestic fishery is a target for fishery enhancement programs. In 1980, the harvest of the domestic fishery was estimated as about 10% of the commercial fishery in Manitoba (Green and Derksen 1984), and 26% of the commercial fishery in Alberta (Alberta Dep. Energy Natur. Resour. 1984). In Manitoba, Green and Derksen (1984) projected a domestic fishery harvest for 1985 of about 1,900 tonnes. This compares with about 4,400 tonnes for the sport fish harvest (Table 3). The domestic fishery, therefore, is significant in terms of harvest. In addition, it has strong social values which increase its relative importance in the overall fisheries sector.

Enhancement Policy

In each of the prairie provinces over the past decade there has been increasing awareness that fisheries management policies alone were insufficient to prevent the decline in fish stocks. As early as 1973 a major development marked the beginning of fisheries enhancement in Alberta. The government instituted the Buck for Wildlife program to help "retain, improve and develop fish habitat throughout the province." This fund, based almost exclusively on levies from hunting and fishing licences, started at a level of $6,300 in 1973, and has grown to a level of $2 million annually by 1986 (Table 5). The initial licence levy of $1.00 was increased to $2.00 in 1977, and then to its current level of $5.00 in 1981. As an example of how the fund operates, its 1985/86 total revenues were $2.1 million; of this, $1.6 million was derived from hunting and fishing licence levies. The remainder was made up from donations, grants, and trust fund interest. The Buck for Wildlife program generally pays about one-half of the cost of enhancement activities, with matching monies from other government departments, conservation groups, and private companies making up the rest.

In 1982, Alberta put forward a Fish and Wildlife Outdoor Recreation Policy which defined the general goals of the Fish and Wildlife Division (Alberta Dep. Energy Natur. Resour. 1982). One of these was "to provide a variety of outdoor recreational opportunities based on fish and wildlife resources," with "emphasis directed towards resources having major shortfalls between demand and supply." To identify these shortfalls, a comprehensive 10-year plan was proposed to describe: (1) present and projected demands for recreational fish; (2) recreation fish resources available; and (3) the habitat base necessary to achieve fish supply requirements. Apart from this planning initiative, which formed the basis for future enhancement policy, the immediate fisheries policy of the Fish and Wildlife Division was directed entirely towards the issues of (1) appropriate use; (2) allocation; (3) management; and (4) enforcement.

Table 5: Annual expenditures for fisheries enhancement projects from special enhancement funding programs.[a]

Year	Alberta (Buck for Wildlife Fund)	Saskatchewan (Fish and Wildlife Development Fund)	Manitoba Habitat Heritage Corporation
1973/74	6,305		
75	89,886		
76	331,753		
77	319,392		
78	180,254		
79	424,425		
80	359,615		
81	483,496		
82	301,383		
83	446,784		
84	478,632		
85	639,749	241,000	125,000
86	997,740	394,400	125,000
1986/87	1,994,320	980,650	125,000

[a] Note that total annual expenditures for fisheries enhancement projects in each province will exceed amounts shown because of allocations from other sources, matching fund programs, etc.

Sources: Saskatchewan Dep. Parks Renew. Resour. 1985, 1986, 1987; Manitoba Habit. Herit. Corp. 1987; K. Zelt, pers. comm., Fish. Wildl. Div., Alberta.

By 1984, the Alberta Department of Energy and Natural Resources (1984) had produced the first assessment of fish and fish habitat as required by the 1982 policy goals. With these assessments came the first identification of fisheries enhancement goals. These included specific strategies for implementation. For many species, long-range goals were directed towards (1) maintenance or enhancement of fish populations through supplemental stocking; and (2) maintenance or enhancement of fish habitat.

Saskatchewan defined a comprehensive fisheries policy in 1983 (Saskatchewan Dep. Parks Renew. Resour. 1983) which placed major emphasis on "a balanced program of increased enhancement...to maintain or increase fish supplies." The proposed action plan to increase and enhance fisheries included:

(1) programs to increase fish stocks and fishing opportunities through fish culture projects and through habitat improvement; (2) protection of existing fish habitat by involving the fisheries discipline to a greater degree in land use planning. To implement this policy, Saskatchewan established the Fish and Wildlife Development Fund in 1984. This fund was similar to Alberta's, in that it used monies derived from hunting and angling licences to support the development of wildlife and fishing opportunities. A 30% impost was levied on each angling licence fee. The fund began at a level of $241,000 in 1984, and had reached $980,650 by 1986-87.

Fisheries enhancement activities in Manitoba were well established before 1976 when the first edition of Manitoba's Sport Fish Stocking Policy and Guidelines was published (Manitoba Dep. Renew. Resour. Transport. Serv. 1976). This policy placed no undue emphasis on habitat degradation, or on fish supply and demand issues, but did nevertheless recommend stocking of fish "where the population has been reduced due to man-made or natural occurrences," and in order to "augment natural populations in heavily fished waters where the spawning area or natural recruitment was inadequate."

In 1983, the Manitoba Fisheries Brance outlined a Provincial Fisheries Strategy (Manitoba Dep. Natur. Resour. 1983) which included as one of its main principles, "Fish habitat is essential to maintain a healthy and viable resource and is therefore a [Fisheries] Branch responsibility." Furthermore, it considered that "resource enhancement, protection and/or rehabilitation" was an important opportunity. This policy was directed mainly towards fish habitat loss and habitat degradation through land use practices, and towards the role of the fish culture program in augmenting present stocks, in restoring fisheries affected by habitat loss, and in creating new angling opportunities.

The means to implement habitat protection and rehabilitation came in 1984 with establishment of the Manitoba Habitat Heritage Program. Its purpose was to improve fish and wildlife habitat and to protect habitat which was most vulnerable to destruction. The Manitoba Habitat Heritage Program was funded from general government revenues at a level of $250,000 per year. Fifty percent goes towards fisheries projects. It differs from the Alberta and Saskatchewan schemes in that its support is not directly tied to hunting and fishing licence fees.

The growing importance of fish habitat degradation as an issue in Manitoba can be seen in a recent Fisheries Branch document entitled "A Strategy for the Management of Manitoba's Fish Habitat" (Manitoba Habit. Herit. Corp. 1987). In this policy document, a leading principle is that "fish habitat in Manitoba must be conserved, enhanced and rehabili-

tated to protect existing resources and increase fisheries productivity to meet user demands and opportunities for the benefit of present and future generations."

Fishery Rehabilitation Measures

The restoration or improvement of fish habitat in the Canadian prairies tends to fall into five major categories.

1. Stream Enhancement

The severe degradation of fish habitat in many streams is characteristic of the Canadian prairies. The flat topography creates significant water drainage problems for agricultural development. Unfortunately, drainage improvement is usually brought about by stream channelization, a process of straightening the stream and standardizing its width and bank slopes. This reduces habitat diversity within the streams and generally changes the water flow regime in a way which is detrimental to fish feeding and spawning. The aquatic community of insects and plants upon which fish depend for food and shelter are often seriously depleted by changes in the water regime.

Livestock production is another activity which degrades fish habitat. When cattle are allowed access to river banks, they graze away riverbank vegetation. The banks then become unstable and erode, releasing silt which smothers gravel beds in the stream. Gravel beds produce many insects on which trout and other fish feed, and provide essential spawning habitat for trout and walleye. Channelization and bank erosion also widen streams, making them shallower. Shallow, unshaded streams become much warmer and are then less suitable for trout and other fish.

Other types of development too, can degrade fish habitat. Dams for municipal water storage and roadways often create barriers to the movement of fish to spawning or feeding areas. Soil erosion and the runoff of pesticides and fertilizers from farming activities have adverse effects upon the chemistry of stream and lake water.

Stream enhancement measures are designed to redress some of these problems. In-stream improvements, such as replacement of large boulders, construction of deflectors to narrow stream width and create stronger currents for scouring the stream bottom, and the construction of culverts or fishways which allow for fish passage around obstacles, are measures which can greatly increase the stream's carrying capacity for fish. The fencing of streambanks and development of specially-designed watering places, are effective in reducing the impact of livestock on streams. Stream banks gradually recover their original vegetation cover and configuration if

left undisturbed. However, if they are severely degraded, special measures are sometimes needed, such as construction of log cribbing, tree revetments, and shoreline deflectors, especially at stream corners. These enhancement measures recreate habitat which has been removed by stream channelization.

In recent years, it has become apparent that stream enhancement need not conflict with the objectives of drainage improvement. It is now realized that the same stream features which contribute to fish habitat (stream meanders, instream boulders, pool-and-riffle bottom configurations, and stable banks) also contribute to the dissipation of kinetic energy of the running water. Uncontrolled, this energy leads to heavy erosion and siltation in channelized streams, and leads to excessive maintenance costs. Tests in Manitoba have shown that when enhancement measures are hydraulically designed, fish habitat can be improved, at the same time reducing the operational costs of drainage improvements.

2. Lake Rehabilitation

Shallow ponds and lakes, characteristic of the Canadian prairies, provide opportunities for fish habitat enhancement. In summer, shallow lakes are heated right to the bottom, but excessive water temperatures kill fish, and trout are particularly susceptible. In deeper ponds, a refuge of cooler water remains at the pond bottom. In winter, shallow lakes suffer from another problem: oxygen, which cannot be replaced through the ice, is removed from the water by respiration of the sediments. In shallow ponds, the total amount of oxygen dissolved in the water is insufficient to meet the sediment's oxygen needs, and all the oxygen is used, resulting in death of the fish. If shallow lakes can be made deeper, they will contain sufficient water to supply the sediment's oxygen needs, with enough left over to support the fish. Rehabilitation of shallow lakes often requires only the construction of a small dam at the outlet to increase and stabilize the water depth - to provide cool water in summer, and oxygen in winter. Another method is to excavate a portion of the lake or pond to deepen it.

Frequently, water bodies such as flooded quarries can support fish, but they have little underwater structure to provide shelter for fish and fish food organisms. Rehabilitation of these ponds involves the creation of habitat by submerging bundles of trees or tree roots, or creating reefs made of old tires or rocks. After rehabilitation, many of these ponds are stocked with trout. However, the trout rarely do well if the lake is infested with coarse fish such as suckers and perch. Fish barriers, such as filters, screens, and drop structures are then used to prevent coarse fish from entering the outlet and inlet streams. Sometimes installa-

tion of fish barriers will be preceded by chemical removal of coarse fish and stocking with trout.

3. Lake Aeration

Lake aeration is an effective means for increasing winter oxygen levels in lakes when the water level cannot be raised by damming or excavation. A compressor forces air through a diffuser pipe which lies on the lake bottom. The bubbles which rise from the diffuser provide some oxygen to the water but, more importantly, keep an area of the water surface ice-free, so atmospheric oxygen can diffuse through into the water.

4. Trout Pond Development

A popular enhancement technique, especially close to urban areas where there are few natural ponds for fishing, is to create new ponds, either by excavation, or by damming a stream to fill a basin. Shoreline areas may be stabilized with rip-rap or vegetation, and access areas may be developed. Underwater shelters may be created to provide habitat, and the pond stocked with trout.

5. Rearing Ponds

Fisheries technology has not yet developed to the point where walleye fingerlings can be raised in hatcheries in the same way as trout. Instead, small lakes and ponds are used as nurseries where walleye fry are reared to fingerling size in a predator-free environment. In some of the large prairie lakes in Manitoba, natural ponds formed behind beach ridges are used to rear fingerlings. The ponds are connected to the lake by ditches and culverts which are opened in the fall so that the walleye fingerlings can enter the main lake. In Saskatchewan, large walleye rearing ponds have been created near sport fishing lakes by dyking elevations slightly higher than the lake. These ponds are fed from streams and can be partially drained into the receiving lake. Other rearing ponds are completely man-made and are totally drainable, so that all fingerlings can be recovered for stocking.

Fisheries Enhancement Initiatives

The strategies for fisheries enhancement differ considerably across the prairie region, partly because of geographical differences and partly because of the importance of different fish species to anglers. For example, the great diversity of stream habitat in Alberta leads to a greater emphasis on trout there than in the other two provinces. In a 1985 census (Canada Dep. Fish. Oceans 1988a,b,c), trout comprised a more important component of the sport fishery (18%) than walleye (12%) in Alberta, and were preferred by more

anglers (32%) than were walleye (23%). In contrast, walleye were the most frequently caught sport fish in Saskatchewan (33%) and Manitoba (57%).

In Alberta, 90% of fish enhancement expenditures under the Buck for Wildlife Program have been used for trout, whereas Saskatchewan and Manitoba have allocated only 20 - 35% for trout, with greater emphasis (40 - 50% of total funds) on walleye alone (Table 6). This percentage may be even greater in Manitoba, where funds spent on walleye or walleye-type habitat, which also supports northern pike and perch fisheries, is close to 74% (Table 6).

These differences are even more apparent when specific enhancement measures are considered. Rearing ponds for walleye, for example, are very important in Saskatchewan, accounting for 39% of the Fish and Wildlife Development Fund (Table 6), whereas Alberta allocates none of the Buck for Wildlife Fund to walleye rearing ponds. The percentage of Manitoba's Habitat Heritage Fund allocated to rearing ponds is deceptively low (18%), and reflects the fact that most of the province's numerous rearing ponds had already been developed and funded by the Fisheries Branch before the Habitat Heritage Fund came into existence.

Saskatchewan differs from the other two provinces in its approach to stream enhancement initiatives, spending only 1% of its enhancement fund for this activity. This compares to expenditures in Alberta and Manitoba, respectively, of 39% and 27%, and total expenditures of $1.4 million and $100 thousand. Nor is lake rehabilitation (5% of enhancement funding) a strong component of Saskatchewan's enhancement strategy, in contrast to its importance in Alberta (31%) and Manitoba (28%). This may simply reflect the fact that Saskatchewan has opted for development of walleye rearing ponds as a high priority at the temporary expense of other initiatives, such as lake rehabilitation, whereas Manitoba had already developed an extensive set of walleye rearing ponds, and can afford to broaden enhancement initiatives to other areas. This is apparent from Table 7, where Saskatchewan's annual expenditures on enhancement initiatives are shown. From 1984 to 1987, there has been a decided increase in the percentage of funds spent for rearing ponds from 8% to 54%, whereas the amount spent on lake rehabilitation has dropped from 17% to less than 1%. Similarly, lake aeration has fallen from a funding level of 17% to 5% over the same period, as has the construction of fishways in streams, from 29% to less than 1%.

Enhancement of the trout sport fishery in Saskatchewan has taken place mainly through development of trout ponds, with some lake aeration and rehabilitation projects, in which coarse fish have been removed with toxicants (Saskatchewan

Table 6: Capital expenditures for fisheries enhancement projects from special fisheries enhancement funding programs[a].

Enhancement Category	Alberta (1973-86) N[b]	Expenditure[d]	% of Category	% of Total
Stream Enhancement	33	1,436.1		39.4
In-stream work	17	762.8	53.1	
Fencing	7	28.3	2.0	
Bank Stabilization	5	585.7	40.8	
Spawning Habitat	4	59.3	4.1	
Lake Rehabilitation	30	1,111.3		30.5
Fish Shelters	4	598.1	53.8	
Fish Barriers	4	227.5	20.5	
Lake Stabilization	15	196.2	17.7	
Research and Development	7	89.5	8.1	
Lake Aeration	7	35.4		1.0
Trout Pond Development	20	1,065.6		29.2
Rearing Ponds	0	0		0
Fishways	-	-		-
Information	-	-		-
Other[a]	-	-		-
Fish Species				
Trout		3,891.0		90.0
Walleye		58.6		1.4
Rearing Pond (Walleye)		0		0
Walleye, Northern Pike & Perch		-		-
Northern Pike		124.3		2.9
Perch		0.5		0
Grayling		250.2		5.8

[a] Alberta: Buck for Wildlife Fund; Saskatchewan: Fish and Wildlife Development Fund; Manitoba: Habitat Heritage Corporation.
[b] Number of projects
[c] Estimated from expenditures in various enhancement categories
[d] Thousands of dollars

Note that total annual expenditures for fisheries enhancement projects in each province will exceed amounts shown because of allocations from other sources, matching fund programs,

Saskatchewan (1984-1987)			Manitoba (1984-1987)		
N[b]	Expenditure[d]	% of Total	N[b]	Expenditure[d]	% of Total
2	16.2	1.0	13	104.7	27.0
8	81.7	5.1	9	108.6	28.0
7	145.3	9.0	7	71.3	18.4
3	413.6	25.6	2	20.6	5.3
7	630.8	39.0	6	69.0	17.8
2	103.9	6.4		-	-
-	12.0	0.7	3	14.2	3.7
	196.1	12.1			
		35[c]		83.1	21.4
		44[c]		126.0	32.4
		-		69.0	17.8
		-		90.7	23.3
		6[c]		4.5	1.2
				-	-
				0	0

etc. Also, the percentage of expenditures allocated to various enhancement categories and fish species reflects only the allocation of the special fisheries enhancement funds, and does not include monies allocated from other sources.

Sources: Saskatchewan Dep. Parks Renew. Resour. 1985, 1986, 1987; Manitoba Habit. Herit. Corp. 1987; K. Zelt, pers. comm., Fish. Wildl. Div., Alberta

Table 7: Percentage annual expenditures for fisheries enhancement projects from the Saskatchewan Fish and Wildlife Development Fund (%).

	1984-85	1985-86	1986-87	1984-87
Rearing Ponds	7.8	22.0	53.5	39.0
Lake Rehabilitation	17.2	9.0	0.5	5.1
Lake Aeration	16.6	13.7	5.2	9.0
Stream Rehabilitation	-	-	1.7	1.0
Trout Pond Development	-	33.0	28.9	25.6
Fishways	29.0	7.8	0.3	6.4
Equipment	29.3	10.6	7.5	11.5
Mobile Hatchery	-	10.1	-	0.6
Information	-	1.3	0.7	0.7
Total Expenditures ($Thousands)	241.0	394.4	980.7	1,616

Sources: Saskatchewan Dep. Parks Renew. Resour. 1985, 1986, 1987

Dep. Parks Renew. Resour. 1985, 1986, 1987). In Alberta, enhancement of trout in lakes is brought about equally by trout pond development and by lake rehabilitation, particularly the placing of shelters for trout habitat (Table 6). In Manitoba, the trout fishery has been supported largely through lake rehabilitation projects (Manitoba Habit. Herit. Corp. 1987).

The strategy for fisheries enhancement depends not only upon topography and relative importance of the various fish species, but also upon the cost of different enhancement measures. The 13-year history of Alberta's enhancement program offers some examples of approximate costs of these initiatives (Table 8). For example, the rehabilitation of stream habitat has three major components, the most inexpensive being stream fencing, at about $480 per km, and the most expensive being bank stabilization at $82,800 per km. In-stream improvements cost $23,900 per km.

In the development of lake and pond fisheries, one of the least expensive strategies is lake aeration at $5,000 per lake (Table 8). This technique requires operation during high risk winters however, and so tends to be an on-going expenditure. Lake level stabilization is relatively inexpensive at $13,000 per lake. Pond development and the installation of barriers to coarse fish are intermediate measures, at a cost of $53,000 - $57,000 per lake. Although the number of examples is too low for a precise estimate, the

Table 8: Cost of rehabilitation measures from the Alberta Buck for Wildlife fund, 1973-1987.

	No.	ha or Km	Total Cost ($)	Cost/ unit ($)
Pond development	20	88.7 ha	1,065,589	53,279/lake
In-stream enhancement	17	31.9 km	762,824	23,875/km
Stream fencing	7	58.5 km	28,317	484/km
Stream bank stabilization	5	7.1 km	585,734	82,848/km
Fish shelter	4	34.1 ha	598,114	149,529/lake
Lake-fish barrier	4	684.1 ha	227,491	56,872/lake
Lake level stabilization	15	1,977.4 ha	196,173	13,078/lake
Lake aeration	7	155 ha	35,429	5,061/lake

Sources: Zelt, Fish. Wildl. Div., Dep. Energy Natur. Resour., Alberta, provided a list of "Buck for Wildlife" expenditures for various fisheries rehabilitation projects between 1973 and 1987. Of these expenditures, capital construction accounts for 85-90 percent. Table 8 was constructed by dividing the total expenditure for a given activity, by the number of lakes or the length of stream affected.

construction of fish shelters in four Alberta lakes has been relatively expensive at $149,000 per lake.

It is difficult to project precise costs of other enhancement programs from the Alberta experience, because each particular lake or stream poses unique problems in rehabilitation. Also, it must be remembered that many of the costs which are charged back to a fisheries enhancement program by one province may be paid from operating funds within the fisheries department in another. An example has been cited in regard to the walleye rearing pond program in Manitoba whose costs, for the most part, do not appear in the Habitat Heritage program. In most cases, the administrative and management costs of enhancement programs are borne by provincial fisheries departments as the salaries of managers and

biologists. It is hoped, however, that the foregoing comparisons of enhancement programs and approximate costs will stimulate cooperative and comparative approaches to enhancement on the part of fisheries departments.

Notably, the benefits from enhancement initiatives are rarely assessed. It has been assumed that precise measurements are not required, because if enhancement programs were ineffective, fishery users would complain. However, as the cost of fisheries enhancement increases, and as more of the costs are borne by users, there will be a need for programs to be more efficient in providing benefits. Therefore, it will become important to be able to assess the relative effects of alternative enhancement strategies.

The Manitoba Fisheries Branch has pioneered assessment of the rehabilitation of walleye spawning habitat. The value of certain stream modifications has been monitored successfully by comparing the production of walleye fry from stream segments before and after stream modification. All three provincial fisheries departments also monitor the production of fry and fingerlings from hatchery programs for trout and walleye, and monitor fingerling production from walleye rearing ponds.

The federal Department of Fisheries and Oceans, in cooperation with provincial fisheries departments, has conducted long-term research to assess the effect of stocking fry and fingerling walleyes into a large (500 km^2) prairie lake, Lake Dauphin. In addition, this program conducted research on other questions basic to fisheries enhancement, such as the measurement of stream habitat degradation, measurement of larval fish drift in streams, and techniques for rearing walleye fingerlings in ponds and in intensive culture systems. More effort will be required in the future to monitor the effectiveness of fishery enhancement practices.

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FISHERIES RESOURCE DEVELOPMENT

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ABSTRACT

Various federal and provincial vehicles which support development of the Plains aquatic resource are reviewed, as well as examples of specific development initiatives that have taken place during the past decade. Finally, the current method of commercial harvest is discussed, and a possible development which may increase production efficiency is proposed.

INTRODUCTION

The term "development" implies an evolutionary process of growth. If the process is to impact beneficially, it must be balanced against existing resource use methods and based on an intelligent understanding and recognition of the biological, technological, economic and social implications of change. Ideally, the outcome of the development process should maximize the economic and social return to the resource user while, at the same time, ensuring the well-being and continuation of the resource for future users. Unfortunately, competition between subsistence, commercial and recreational user groups often works against satisfying such an ideal, usually to the detriment of the resource. It is, therefore, important that before implementation, development initiatives be measured against criteria that will ensure the protection of the resource in order for it to meet the needs of current and future user groups.

The following, although focussing primarily on the commercial aspects of development, indicates the approach that has been taken in addressing fisheries development in the Plains region.

Canada produces approximately 50,000 tonnes of freshwater fish annually, or about 4% of the total of all fish produced in this country. The fisheries resource of the

three prairie provinces accounts for approximately 40% of Canada's freshwater fish production; the combined production of the three prairie provinces has ranged from 14,500 to 24,500 tonnes annually over the past decade. Manitoba accounts for approximately 70% of this amount, Saskatchewan 20%, and Alberta 10%. The social and economic importance of the fishery is evidenced by the fact that approximately 5,700 self-employed fishermen and crewhands derive all or part of their income from the resource.

DEVELOPMENT

Federal aid for the development of the fisheries industry has been given to reduce harvesting costs, to increase the exploitation of under-utilized species, and to upgrade product quality. The enabling legislation for this assistance is the Fisheries Development Act, which provides for projects to exploit fishery resources more efficiently, to explore and develop new fisheries, to introduce and demonstrate new types of fishing vessels, equipment and techniques, to develop new fishery products, and to improve the handling, processing and distribution of fishery products.

Until some two years ago, the Central and Arctic Region of the Department of Fisheries and Oceans (DFO) had an active Fisheries Development Program, complete with dedicated personnel and appropriate financial backing. Since that time, the program has been downsized nationally, and it has been totally eliminated in the Central and Arctic Region, as well as in the Pacific Region.

Apart from the Fisheries Development Program, administered by DFO, various other programs and agreements contribute to development. These include federal/provincial subsidiary agreements under the Economic Resource Development Agreements; programs such as the Program for Industry/Laboratory Projects and the Industrial Research Assistance Program, both of which are designed to encourage applied research and to transfer technology to advance industry development; and the Panel for Energy Research and Development under the National Energy Program, which has provided funding support for resource-related energy conservation projects, such as waste heat aquaculture studies.

Past proposals and requests for development assistance, and those now being brought forward, relate to a wide variety of potential initiatives ranging from alternate harvesting techniques to new products and processes, some with merit and some less than practical. When it was actively administering a development program, the Central and Arctic Region of DFO applied four basic criteria to evaluate and priorize proposals. These included: (1) the extent to which the proposal would benefit fishermen; (2) the distribution and magnitude

of the potential benefits; (3) the social implications of the proposal, particularly as it may affect those in remote communities; (4) the compatibility of the proposal vis-à-vis resource management goals.

Among the developments which have occurred over the last decade one of the more significant has been the formation of the Freshwater Fish Marketing Corporation (FFMC). Since its establishment, FFMC has been the focus of continuous controversy, generally revolving around the dissatisfaction of fishermen with FFMC's marketing efforts, the prices paid to fishermen (particularly for under-utilized species), and the limitations placed upon entrepreneurial initiatives due to the single desk selling prerogative of FFMC. This last has had some legitimacy in that any would-be value added processor must have FFMC's support, be licensed by FFMC, and must purchase raw material through FFMC, rather than directly through fishermen (at lower costs). Although any producer of fish may sell directly to consumers, recent changes in Alberta, negotiated through FFMC, have resulted in fishermen now being permitted to sell fish directly to retailers within that province. Similarly, Saskatchewan has introduced new fish marketing regulations which permit fishermen to sell fish to special dealers, who in turn may sell the fish to retail stores and restaurants within the province.

In defense of FFMC, its single desk selling power has facilitated the expansion and development of new markets, and has provided greater control and consistency in respect to product quality. For many native fishermen in remote areas, whose economic status was controlled to a large degree by United States companies that imported their product, FFMC has provided improved security through fairer pricing practices. Under FFMC, initial prices are established and guaranteed for individual species and grades at the beginning of the year, and all profits, after administration and overhead costs in excess of established prices, are returned to the fishermen in the form of an adjusted second payment at the end of the year.

Developments in other areas have ranged through resource enhancement, evaluations of alternate harvesting methods, product development, waste utilization, and market assessments. As with any development initiatives, some have been successful while others have been less so. In all cases, the existing knowledge base has been enlarged.

FISHERIES DEVELOPMENT PROGRAM

Some of the development initiatives carried out by the Central and Arctic Region under the Fisheries Development Program include:

1. Mobile Processing Plant

Limited capital funding for the construction of new fish processing plants is a perennial fisheries problem, especially in respect to road accessible, low quota lakes, where the harvest is of short duration. To overcome this problem, the Fisheries Development Program undertook to design, construct, test and demonstrate a mobile fish processing plant (Dilk 1976; Friesen 1982).

Subsequent use by the industry of the mobile fish processing plant has been impressive. The plant can service several lake sites annually; it is suitable for servicing fishing areas within federal or provincial parks, where permanent facilities are discouraged or prohibited; and it has been demonstrated that the plant can operate efficiently in remote areas without support facilities.

2. Winter Fishing Equipment

This project aimed to provide equipment that would reduce the discomfort of winter fishing, increase efficiency and improve product quality. The equipment consisted of an aluminum shed, containing an hydraulically operated net reel and winch to set and retrieve gill nets, which was mounted on skis so that it could be pulled by a Bombardier. The equipment included a separate insulated aluminum shed for storing and transporting fish to packing plants.

3. Graham Yawl

The Graham yawl (Popko, 1977) was conceived and designed originally by Al Graham, the former Chief Instructor of the Manitoba Fisheries Centre at Hnausa. It was developed jointly by the province of Manitoba and DFO.

The vessel is 6.7 m long, with a 2.6 m beam. It is powered by a 140 hp inboard-outboard Mercruiser capable of speeds to 70 kmh. It has a centre-mounted hydraulically operated net reel, a load-carrying capacity in excess of 900 kg, and stern-mounted, insulated fish holds. Two fishermen can handle 30 nets a day (approximately 2,700 m), in comparison to the 10 to 15 nets a day which can be set by two fishermen working from a wooden yawl.

4. Whitefish Caviar

Until its use as caviar was initiated by DFO 10 years ago, whitefish roe was a wasted by-product (Iredale and York 1983). At that time, Japan was identified as a test market, primarily because the Japanese greatly valued herring roe and increasingly imported that product. Eventual Japanese consumer resistance to the high herring roe prices and the sub-

sequent market decline in 1979 and 1980 had a dampening effect on all roe products, particularly a relative newcomer like whitefish roe.

The FFMC, therefore, turned its attention to the North American market. At first, a non-pasteurized fresh product was introduced in two packaging formats, one a 30 g net screw-top glass jar, the other a 220 g round metal can. Both required strict refrigeration control during distribution and retailing. The very short shelf life of the product (approximately 2 1/2 months at 2° - 4°C), and the difficulty of maintaining low temperature during distribution and retailing, demonstrated the impracticality of either packaging format.

The next container to be selected was a 106 g round metal can, close to the maximum size that would permit successful pasteurization. The pasteurization process extended the product's shelf life and reduced the requirement for constant low temperature maintenance. This container met the essential requirements for a pasteurized product: it was tamper-evident, it allowed for headspace vacuum, and had an embossable surface to record process code data. Although this container was used for three years, its use was eventually discontinued, largely because the metal can's lining enamel was not formulated to resist the action of the salt in the product, which in turn led to the development of off-flavours. In addition, the metal can was considered to be an inappropriate container for caviar.

Finally, a 50 g glass jar was selected, which has the required features, including a tamper-evident aluminum twist-off lid that can be embossed with a process code and vacuum-sealed. In addition, such jars provide visability of the caviar to enhance its consumer appeal. Between 1,800 and 2,700 kg of pasteurized whitefish roe packaged in this container is now marketed annually in North America. A further 1,400 to 1,800 kg is frozen and marketed outside North America.

5. Low value species utilization

Burbot

Developing an improved market for low-value species, such as burbot, is an ongoing concern. In 1974, the province of Manitoba, DFO, and FFMC undertook a joint project to produce, process and develop a market for burbot. The intent was to produce a competitively priced, boneless fish portion as a cod replacement product for a health care institution in Winnipeg. Production was by trapnetting, and processing took place at the Manitoba Fisheries Centre at Hnausa. Unfortunately, production volumes were poor, the recovery of a bone-

less, pre-weighed portion was low, and problems were encountered with the product's texture.

A further project in 1981 and 1982 was more successful, when an Alberta processor was contracted by DFO. A price for burbot from Lesser Slave Lake fishermen was negotiated and agreed to, shipping, handling, processing, and marketing costs were identified, and it was agreed that those costs would be covered by DFO, so that the processor's risks would be nullified.

In 1981, the first year, 2,250 kg of burbot were produced, processed and successfully marketed, with all costs being covered by the revenue from the product. In the second year, production was increased to 4,500 kg, which was also marketed successfully. Although the utilization of burbot continued after this, its use has become sporadic, primarily because the processor and the fishermen disagreed over landed prices. However, the project did demonstrate that burbot could be processed and marketed successfully.

6. Parasite-infested coregonids

Parasite-infested whitefish and tullibee have been the focus of a more recent DFO project, although the pre- and post-harvesting options to address the problem remain limited.

Candling fillets of harvested fish to find and remove parasite cysts is effective, but the method is labour intensive and it damages the fillets. An alternative approach has been the application of the Japanese surimi technology. In this process, the fish are mechanically boned to produce a mince, the mince is washed and decanted a number of times, drained to reduce the moisture content to its original level, and then the material is strained.

The initial deboning to produce mince reduces the particle size of the parasite cysts; the repeated washing and decanting floats off cyst particles and the yellow, residual waste from the cysts, and the final straining helps to develop colour uniformity. The resulting mince material is very light in colour and little different from mince processed the same way using non-infested fish.

Finally, blending the material with cyroprotectants, including sugar and phosphates, results in surimi, a stable intermediate product. This is frozen and eventually used as the base material for further manufacture into the various seafood analogues, such as imitation crabmeat and other crustacean substitutes.

Despite the success of this process, further development

is being impeded by the relatively high cost of surimi based on freshwater species in relation to seafood analogues that use ocean species as their base material. Pollock, the species most commonly used as the base material in surimis, nationally and internationally, has a landed value on the Canadian east cost of between 44 - 74% less than cutter grade parasite-infested whitefish, and 20 - 63% less than tullibee of the same grade.

7. Silage

Other work initiated by DFO has included by-product development, using processing plant fish wastes as silage for use as an animal feed supplement. (Ward et al. 1985).

The process is simple: fish waste is ground, blended with acid, and heated slightly while stirring the slurry. The addition of acid, in combination with heat, accelerates the action of enzymes naturally present in the ground fish waste, and this causes autolysis of the material to a liquid state. Acidification also inhibits bacterial growth, thus preventing putrefaction.

The product has been shown to be valuable in hog diets, but an aggressive marketing effort will be needed to obtain fair market value based on the product's protein content. If the introduction and encouragement of suitable liquid feeding systems is initiated, the demand for this type of feed supplement may increase. The production of silage potentially may provide income, as well as a means of utilizing fish wastes and by-catch in situations where their disposal creates a problem or a cost to a fish processing plant. As the product is bulky, production should take place close to a market large enough to provide user alternatives. The establishment of a silage operation at a major fish production centre might be vertically integrated with a new hog-rearing facility.

8. Crayfish

Recently, the crayfish resource in Saskatchewan has been evaluated by the Saskatchewan Research Council (Sawchyn 1986), a project funded by DFO, using monies from the Fisheries Development Program.

Twelve pre-selected sites throughout the province were surveyed to determine whether crayfish of a suitable size could be found in sufficient quantities to satisfy export market requirements.

The survey's results were mixed. While it was determined that lakes in southern Saskatchewan were the most promising sources of crayfish in respect to both size and

numbers, it was also found that none of the sites provided a significant number of specimens exceeding 9 cm. the size considered the minimum for export into the Scandinavian markets where a demand exists.

The crayfish were collected by hand as they did not respond well to any of the variety of other trapping methods used. Specimens were held temporarily in tanks at lakeside, and then transported live on ice for processing. The crayfish were boiled, as they are in Scandinavia, and they were then vacuum packaged.

Test marketing in Scandinavian countries showed them to be unacceptable because of their small size. However, considering production and transportation costs, it is doubtful if Saskatchewan crayfish could be competitive even if size were not an issue.

9. Mobile Walleye Hatchery

This project, funded under the Fisheries Development Program and reported in these proceedings, was initiated with a feasibility study and a cost/benefit analysis in 1983/84, followed by design and construction in 1984/85 and on-site field testing in 1985/86 (Giles and Foster 1987).

POTENTIAL FISHERIES DEVELOPMENT

What is the relationship between the commercial production of fish and market demand, particularly in the light of the public's increasing demand for fresh fish now?

The existing and predominant gillnet fishery is inefficient for a number of reasons. Among these are a variable and unpredictable supply; lack of public demand for species produced; frequent mortalities; and deficiencies in product quality. The seasonally associated peaks and valleys in production have a negative impact on the processing sector of the industry, which also affects the market for fish. Periods of peak production can overextend processing plant capacities, resulting in frozen inventory carry-overs, quality loss, and high energy use. Periods of low production can result in processing plant shutdowns, and employee layoffs. However, the problems of quality loss and much of the frozen storage inventorying, together with the costs associated with these problems, are incurred only after fish are removed from the water.

Ideally, a system not unlike aquaculture methods, which allows the production and selection by species and size to be determined by both market demand and processing plant capacity, would increase industry efficiency and favourable influence stock management. The use of small net impoundments,

or holding pens, to maintain a live product inventory may be an option. Besides its use in aquaculture, the concept of live storage has been used to advantage in capture fishery. A Canadian example of this concept is the holding of sea-run char in pens after harvesting using a fish weir or saputit (Kristofferson et al. 1986) The holding pens are an integral part of the weir structure. This harvesting method was introduced in the Northwest Territories from 1980-83 under the Fisheries Development Program. This production method permits the fish to be held live until they can be flown to fresh fish markets where they obtain premium prices. Spoilage is virtually eliminated and the product is of top quality.

The concept of live product inventory in the Plains region commercial fishery would require the use of some form of trapping as the harvesting method. The fish would subsequently be stored in small net impoundments, holding pens, or in the trap itself. Such storage methods would permit close regulation of production to meet market needs on demand, species and size selection, optimum quality, minimal frozen inventory, and improved stock management. It would also stabilize processing sector employment.

The effectiveness of trapping techniques might be a problem in this system. Other obvious drawbacks would include the cost of new equipment, the seed costs of net impoundment or holding pens and their maintenance during the winter months; and the cooperation of fishermen and producers would be required in the adoption of an alternative production system. Given the dictates of the market as the primary influence in the degree of success or failure of the industry, however, this type of "market considerate" approach may be worth examining.

Development and improvement of the Plains resource will occur only if the level of interest and the dedication of individuals continues. The Plains resource is unique, and its enhancement must remain a priority.

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